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# An Exhaustive Review on Internet of Things from Korea's Perspective

**Shapna Muralidharan[1] · Abhishek Roy[2] · Navrati Saxena[1]**

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**Abstract** After the World Wide Web in 1990s and the mobile internet in 2000s, we are gradually moving towards one of the potentially most distinct phase of internet revolution—The "Internet of Things (IoT)". IoT is an emerging concept, based on the convergence of legacy technologies, like RFID, WSN and smart objects, for connecting billions of "things". Such a massive connectivity generates a huge data for analysis, processing, mining and storage. Moreover, the inherent heterogeneity of IoT is also raising significant technical and application challenges. Many countries are innovating and adapting IoT for the development of the country's economy. Korea, being a digitally advanced country, is already ranked second in "suitability of preparedness for IoT opportunities". In this paper, we first mention the vision, capabilities and status of IoT. Next, we discuss the architectural requirements and popular global IoT projects. Subsequently, we review the history, research plans and applications of Korean IoT. Finally, our work concludes with a list of major open issues and challenges faced by the Korean IoT industry with pointers to possible solutions.

**Keywords** Internet Of Things (IoT) · IoT architecture · IoT Korea · IoT applications · IoT prospects

✉ Navrati Saxena
navrati@skku.edu

Shapna Muralidharan
shapna2013@skku.edu

Abhishek Roy
abhishek.roy@samsung.com

[1] Department of Electrical and Computer Engineering, Sungkyunkwan University, Suwon, South Korea

[2] Advanced Technology Group, Samsung Electronics, Suwon, South Korea

## 1 Introduction

The Internet of Things (IoT) is a novel, emerging paradigm with multiple visions. It was first proposed by Kevin Ashton (MIT Auto ID center, 1990) [1] and developed after Weiser's introduction of ubiquitous computing (Xerox PARC, 1988). The basic concept of IoT lies in converging and linking the physical and virtual objects to create "a world where objects are seamlessly integrated across the borders, anytime, anywhere, anything and by anyone". IoT is generally characterized by identifying, locating, tracking and managing things by exploitation of data capturing, modeling and analysis [2]. The technology including the 'things' (objects, vehicles and people) has to be equipped with embedded sensors, RFIDs, actuators and processors. Gradual reduction in size, weight, cost and energy consumption of small electronic devices, together with the increasing penetration of RF tags have contributed significantly to the concept of IoT [3]. Being in its initial development stage, IoT currently has no standardized definition. A set of major definitions is tabulated in Table 1 and illustrated in Fig. 1.

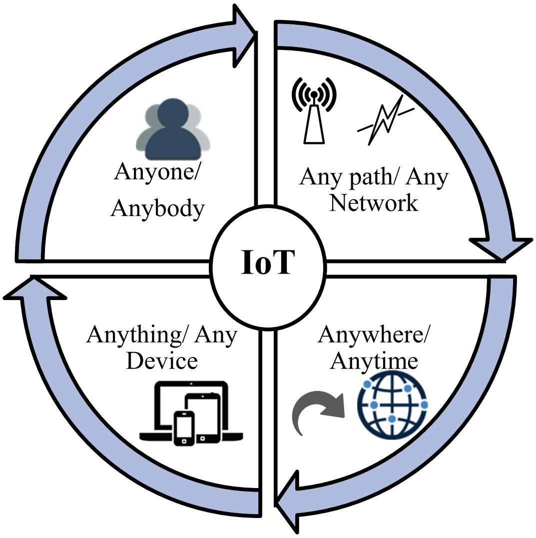
Based on the above definitions, mentioned in Table 1, we first identify three important requisites for IoT design:

1. *Complex Knowledge* IoT consists of a large number of autonomous sensors and actuators. The communication between various devices depend not only on the device capabilities, but also on the physical world. The identification and the localization technologies needs to be smart enough to recognize the physical world and resolve the complex perception of the IoT environment [4].
2. *Intelligence* Millions of connected devices generate a huge amount of data. This huge data demands an intelligent computing paradigm, like cloud computing. Sophisticated data analysis and mining techniques are required to capture the relevant knowledge from this huge data. Context awareness should be explored to analyze and get useful data.
3. *Communication Technologies* Communication technologies include a wide variety of wired and wireless network, equipped with heterogeneous nodes and gateways. IoT not only uses interactions among the physical and virtual world, but also explores

**Table 1** IoT definition from various organizations

| Organizations | Definition |
|---|---|
| Cisco | Network of physical objects accessed through Internet. These objects contain embedded technology to interact with internal states or external environment [5] |
| ITU-T | Global infrastructure for Information Society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving, interoperable information and communication technologies [6] |
| CASAGRAS | Global network infrastructure, linking physical and virtual objects through the exploitation of data capturing and communication capabilities [7] |
| CCSA | A network, which can collect information from the physical world or control the physical world objects through various deployed devices, with capabilities of perception, computation, execution and communication [8] |
| European Commission | World-wide network of interconnected objects, which is uniquely addressable, based on standard communication protocols [9] |

**Fig. 1** Concept of IoT




socio-technological interactions. Hence, communication reliability needs to be ensured.

With these definitions and the requirements of an IoT environment, we now discuss the country-wise development of IoT. European Union (EU) has invested more than 100 million Euros in a series of new research projects through the Seventh EU Framework Program (FP7 for R&D). These projects are getting actively deployed in smart grids, intelligent transportation, smart cities, etc. [10]. China is gearing up their IoT development by releasing new 12th Five-Year plan on IoT deployment [11]. Korea, on the other hand, currently has more than 40 million connected devices. It is expected to reach more than 60 million by 2020 [12]. A trilateral collaboration between academia, industries and government are generating advanced models for the promotion of IoT [13]. This has already put Korean IoT in second position, behind USA, in "suitability of preparedness for IoT opportunities" [14]. Many significant domains, like health care, smart grids, logistics already involve IoT. The Korean government has invested US$ 27.8 million in fundamental technology development, test bed advancement and standardization of IoT. The test bed for smart grids have been laid out in Jeju Island, Korea [15]. Similarly, smart cities are getting commercialized in Seongdo (40 km south of Seoul, Korea).

In this paper, we have taken an in-depth look into IoT, with a focus on Korea's perspective. Our major contributions are summarized below:

1. We first discuss the status, vision and capabilities of IoT.
2. Next, we delineate the IoT's architectural requirements, major global architectural project and Korean IoT architecture.
3. Subsequently, we take a detailed look into the history and future research plans associated with Korean IoT.
4. In an attempt to characterize the increasing influence of IoT in Korea, we describe the major IoT applications in Korea.

5. Finally, we point out the major challenges and open issues associated with IoT and suggest some possible solutions.

The rest of the paper is organized as follows: Section 2 analyzes vision, status and capabilities of Korean IoT. We analyze an open generic architecture for IoT, specific to Korea, in Sect. 3. Section 4 discusses the history and research plans for IoT in Korea. Section 5 summarizes the current IoT development of various applications in Korea. Section 6 points out the challenges and open issues faced by Korean IoT industry and also suggests some prospective solution. Finally Sect. 7 concludes the paper.

## 2 IoT: Vision, Status and Capabilities

IoT is surging ahead as the new major trend in Information and Communication Technology (ICT). In order to connect billions of devices, enriched with communication capabilities, IoT needs to use not only existing communication technologies, like RFID and WSN, but also demands new innovative approaches [16]. Hence vision of IoT, current status and capabilities are discussed in this section.

### 2.1 Vision of IoT

Recent innovations in IoT are achieved by seamless embedding of electronics into everyday objects, thus paving the way for new services and applications. This concept has accredited the perception of a global infrastructure of interconnected networks of heterogenous, physical and virtual objects. Data captured and interpreted from these objects are analyzed, processed, mined and stored. One major challenge lies in efficient decision making using this captured data. In addition, security, privacy and trust management are essential features to envision a prospective IoT environment.

From Korea's perspective, IoT's major vision is to promote the usage of innovative ICT technologies to foster creativity and trigger economic growth. The Korean government is collaborating with research institutes like ETRI [17] to promote IoT in a wide spectrum, from healthcare to automated payment solutions. These notable developments ensure positive growth in Korean IoT industry, thereby supplementing country's economic growth.

### 2.2 Status of IoT

IoT can be foreseen as an enhancement to existing communication between people and applications through a new scope of "things". It creates a new intelligent, invisible network that can be sensed, controlled and programmed. Recent forecasts show that there will be 50 billion connected devices globally by 2020—a massive increase from 14 billion in 2014 [18, 19]. Early stages of research and development in IoT shows direction on domain-specific operations. The applications developed needs to satisfy the specific industry requirements. The services rendered should be gradually integrated with the industrial production and business models. The status is now gradually changing by involving cross-domain specifications and heralding a world of convergence.

Currently Korea's IoT is mostly focused on the development of convergence in specific fields, like ship-building and food industries. It also involves a government policy with specific roadmap on ICT convergence across all industries. Rapid progress in the design of smart cities and test beds [13, 15] are demonstrating the initial results of Korea's IoT research and development. This vision of IoT is shown in Fig. 2. Furthermore to cope with this ever-increasing appetite for data, networks have already rolled out LTE Advanced technology in Korea. LTE offers faster data rate transfer which in higher download and upload rate. LTE's high speed and low latency will provide a connected, ubiquitous IoT environment.

### 2.3 Capabilities of IoT

Figure 3 shows the major capabilities of IoT applications.

1. *Location Sensing*
   *Tracking Information* IoT collects information on the basis of location of people, inventories and logistics. Subsequently, it provides services based on the information collected. RFID tags are used in tracking location and trigger smart alarms during an unwanted interference (as outage in smart grids) [20].

   – *Fleet Management* Fleet (vehicle) management includes different parameters, like vehicle maintenance, vehicle telematics (tracking and diagnostics), driver management, speed management, fuel management and safety management [21]. In logistics, IoT improves not only material flow systems but also the global positioning and automatic identification of freight. IoT is expected to bring profound changes in the global supply chain by intelligent cargo movement. This requires continuous synchronisation of supply chain information and seamless,

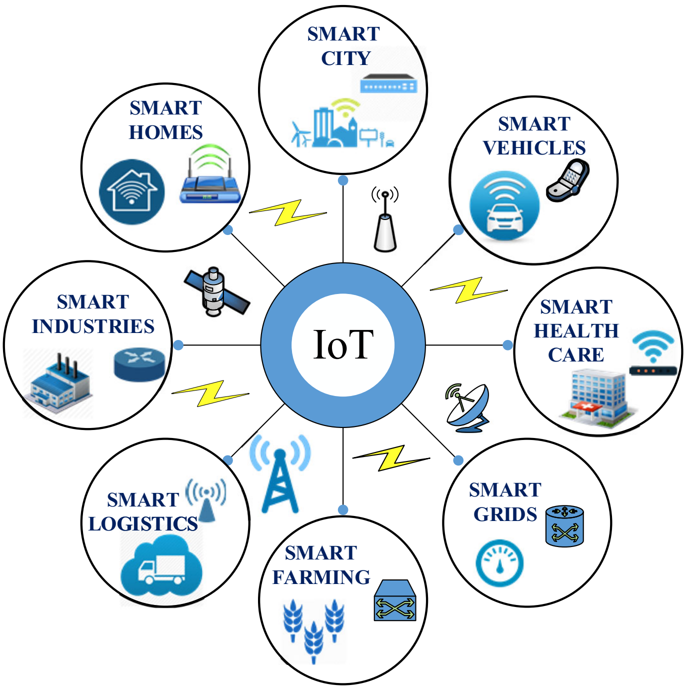



**Fig. 2** Status of ICT convergence in Korea

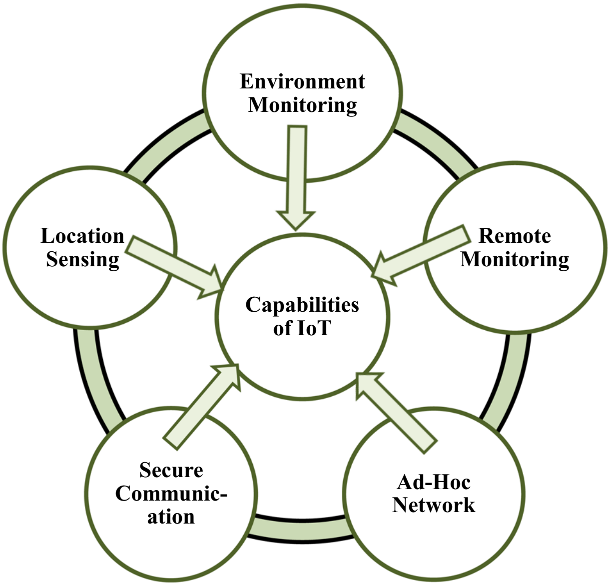



**Fig. 3** Capabilities of IoT applications

realtime tracking of objects. It will make the supply chain transparent, visible and controllable, enabling intelligent communication between people and cargo/goods.

– *Traffic Monitoring* An integral part in smart city infrastructure is traffic monitoring. Traffic Monitoring provides efficient control and management over city's traffic by using advanced technology of sensors, information and network. Traffic monitoring is used in emergency situations, environmental pollution control, triggering alerts on traffic congetsion, avoiding and reporting accidents etc. These type of applications exits in many countries US, Brazil and Korea [22].

2. *Environmental Monitoring* IoT systems can help in monitoring environmental conditions like temperature, humidity, pressure, noise, radiation and pollution. IoT is the key to solve many global challenges, like providing power, food and a clean, pollution free environment. Smart monitoring of water and soil attributes help in smart agriculture and water conservation. We now describe the major IoT-applications, prevalent in Korea [23]:

   – *Smart Environment* IoT offers efficient solutions for environment monitoring. This includes pollution control (e.g. Gwangyangman National Industrial Complex Air Pollution Monitoring System, Korea), disaster forecast, like volcanoes, forest fires and earthquakes. Large number of sensors collect data and trigger the alarm to take appropriate proactive measures.
   – *Remote e-health Applications* By collecting real-time data from a person's body, IoT can aid in remote health monitoring. This can improve the quality in medical sector by taking timely action and saving lives [24].

3. *Remote Monitoring* In applications like smart homes, people can control and monitor devices remotely, according to commands given through applications [25].

- *Appliances Control* Smart homes allow people to control appliances using IoT. Existing smart homes are gradually gaining popularity in emergency detection, anti-theft and efficient indoor energy management.
- *Disaster Control* IoT systems can sense and trigger the necessary controls during natural disasters like landslide and volcanoes. Moreover, it is also going to be an integral part in the emerging smart grids. IoT increases the reliability of smart grids by making efficient forecast of power blackout and issuing proactive prevention and control.

4. *Secure Communication* IoT can establish secure communication between the devices based on application specific requirements and capacities [26, 27]. Technologies and services are developed with suitable security and privacy features from the designing stage. The personal data generated is ensured to be safe and private.
5. *Ad-hoc Network* Ad-hoc network makes IoT capable of internetworking in vehicular networks. In order to transfer data between vehicles, the network reorganizes and forms a pervasive connectivity. This enables the travelers and visitors informed about accidents and traffic congestion [23].

**Table 2** Existing IoT architecture related projects

| Project | Objective |
|---|---|
| IoT-A [29, 30] | • Architectural reference model for interoperability, principles and guidelines for protocol, interface and algorithm<br>• Assess existing IoT protocol suits, mechanisms for end-to-end inter-operability and seamless communication<br>• Develop IoT device components, like device hardware and run-time environment |
| SENSEI [31] | • An Integrated Project in the EU's Seventh Framework Programme<br>• Scalable framework and protocols for easy plug and play integration of globally distributed WSN<br>• Efficient wireless sensor and actuator island solutions<br>• Pan European test-bed |
| SPITFIRE [32] | • Provide applications transparent of network diversity and complexity<br>• Automated introduction of new devices by self-configuration<br>• A unified SPITFIRE GUI to make user-friendly interaction with SPITFIRE components |
| ASPIRE [33] | • Advanced Sensors and lightweight<br>• Programmable middleware for Innovative Rfid Enterprise<br>• A lightweight, royalty-free, programmable, privacy friendly, standards-compliant, scalable, integrated and intelligent middleware platform<br>• Low-cost development and deployment of innovative fully automatic RFID solutions |
| FI-WARE [34] | • An open, public and royalty-free architecture with open specifications<br>• Open APIs for developers across multiple vendors, thus protecting developer's investment<br>• Efficient response to the customer's as well as enterprises' and organizations' demand |
| ETSI M2M [35] | • Develop an end-to-end telecommunication high level architecture for M2M<br>• Based on a "Store and Share" resource based paradigm<br>• RESTful architecture style |

After reviewing the vision, status and capabilities of IoT, in the next section we will discuss the existing architectural projects, functional requirements and proposed architecture for Korea.

## 3 IoT Architecture

The current IoT is actually a network of networks with certain unique characteristics. In IoT it is envisioned that, physical things or devices will have different types of sensors/ actuators connected via internet or any other heterogeneous access networks. IoT is enabled by technologies like embedded sensing, actuating, RFID, WSN, real-time, and semantic web services. To manage this wide variety of technologies involved and the data generated from a number of devices, IoT needs an appropriate architecture such as a service oriented, content-centric or a thing-centric architecture. Moreover, the protocols need to be efficient to cater the diverse IoT devices, sensors and services.

### 3.1 IoT: Architectural Projects

Over years a number of IoT architecture related projects [28, 29], like IoT-A [30], SENSEI [31], SPITFIRE [32], ASPIRE [33], FI-WARE [34], ETSI M2M [35] have been implemented. Based on the scope of the project objectives, the protocols and the architecture are different. The IoT architecture projects are detailed in Table 2. Heterogenous applications, together with different architecture and protocols have made inter-operability a major hindrance in growth of IoT. This motivates researchers to define an open IoT architecture, i.e. a standardized version to reduce total cost of deployments [36]. As shown in Fig. 4, Generally, the architecture of IoT is divided into five layers [37, 38]. Table 3 briefly describes these layers.

### 3.2 IoT Architecture-Generic Requirements

For designing an open IoT architecture, we need to evaluate the functionalities demanding common solutions. The set of major required characteristics of an inter-operable architecture are mentioned below [39, 40]:

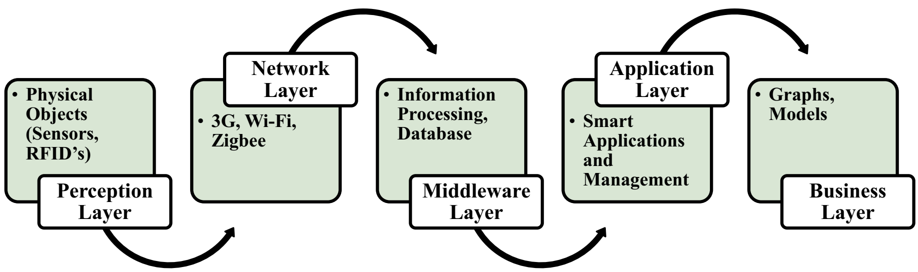



**Fig. 4** Generic architecture of IoT

**Table 3** Layers in IoT Architecture

| Layer | Properties |
|---|---|
| Perception layer/ device layer | • Physical objects and sensors<br>• Object-specific information and identification by sensors<br>• Information is passed to network layer |
| Network layer | • Addressed as "Transmission Layer"<br>• Send information from sensors to information processing system in a secured way<br>• Wired or wireless,(4G, UMTS, wi-fi, Bluetooth, infrared, zigbee etc.) transmission<br>• Information transfer from perception to middleware |
| Middleware layer | • Information processing and ubiquitous computation<br>• Efficient information storage in relevant database<br>• result-based service management and decision making |
| Application layer | • Application management based on the middleware's results<br>• A wide scope of applications, like smart health, smart farming, smart home, smart transportation etc. |
| Business layer | • Manage the overall IoT system—from services to applications<br>• Efficient business models based on the analysis of result |

1. *Contextual Information of Sensors* The context awareness of sensors (what, when, who, how and why) is an important factor, as millions of devices will be connected. The data stored needs to be easily retrieved when it is required.
2. *Scalability, Flexibility and Openness* An open IoT architecture, which has open standards and interfaces that can increase the scalability of performance and flexibility. The open architecture should be adaptable to different applications in a flexible way.
3. *Socio-Technical Challenges* As IoT is human centered, a few socio-technical challenges involved are, standard protocols, security and privacy. There are privacy concerns for certain data collected from people [41].
4. *Standard Protocol and Interface* An analysis of various proposed IoT architecture, in various private projects helps in modeling a generic open IoT architecture. A set of standard protocols like IPv6 over Low-Power Wireless Personal Area Networks (LoWPAN), Routing Over Low power and Lossy networks (ROLL) needs to be developed [42]. To summarize, the main attributes that an IoT architecture should support are: *sustainability, interoperability, facilitating collaboration, supporting experimentation*

Korea's IoT domain covers a wide spectrum of diverse applications. It is challenging to specify one single architecture satisfying the entire set of applications. The identification of a reference model for the entire IoT domain will provide a common ground. In 2009 a group of researchers from more than 20 large industrial companies and research institutions joined to detail out a common IoT architecture. This flagship project of European Union's 7th Framework program for Research and Development [10] is termed as "Internet of Things-Architecture (IoT-A)". IoT-A has proposed a possible Architecture Reference Model (ARM) for IoT systems [28, 29]. The main objective of IoT-A is to build a reference IoT architecture provide a common structural guidelines for core aspects of developing, using and analyzing IoT systems. The IoT-A project has proposed two models—IoT RM, IoT RA, from which a reference architecture model for IoT systems in Korea is proposed.

### 3.3 Proposed IoT Architecture for Korea

Figure 5 demonstrates the functional view of Korea's IoT architecture. It incorporates a layered model and introduces all the essential functional elements. The reference model is layered, open and service oriented. The architecture complies with the core features like,

- The underlying connectivity protocols
- Connectivity and network management
- Resource and service management
- Semantics and knowledge management
- Security and privacy
- Application and services

Various applications like logistics, health, utilities have to satisfy a wide array of requirements. This has resulted in discrete interfaces, protocols and functionality. To overcome this hindering block and for a progressive development of IoT this IoT-A project is proposed. It has systematized IoT architecture with a design which will help, designers to have a concrete architectural design especially for Korea. With these above-mentioned IoT architectural issues, we now illustrate the history and research plans of IoT in Korea.

## 4 History and IoT Research in Korea

Over the past few decades, Korea's ICT industry has made great contributions to the economic growth since 1990s. Recently Korea has been ranked first in ICT development for the past three years. Most of these ICT industries heralded the initial research and development needed for Korea's IoT-related projects.

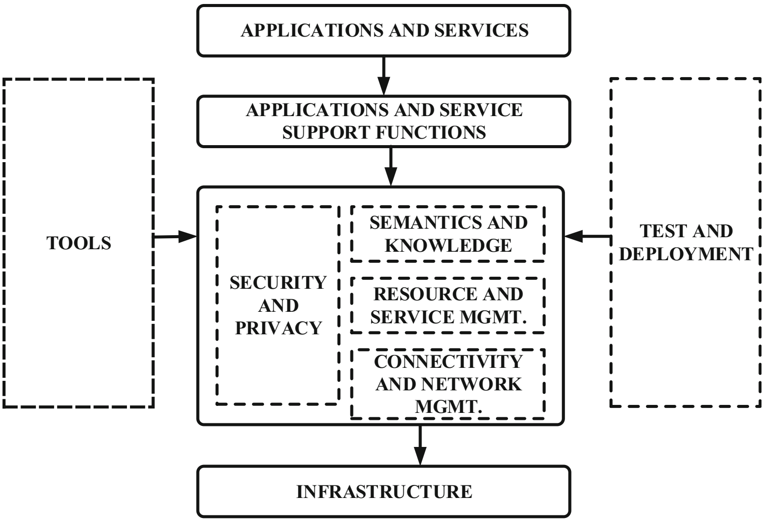



**Fig. 5** Architecture Reference Model (ARM) for Korea

### 4.1 Korea's IoT Research History

Different IoT-related projects, like NII, IT839 have been actively pursued since 2000. In 2004 the Korean government proposed a new strategy called IT839 for developing both technological infrastructure and information convergence capabilities [43]. The main objective is to develop ubiquitous sensor networks (USN) and next generation internet address system (IPv6) for initiating the IoT vision. The eventual changes in IT environment, including the contents, terminals and network digitalization have resulted in the development of ubiquitous services in various Korean industries.

In 2013, the Ministry of Science ICT and future Planning (MSIP) has included IoT in the list of emerging technological trends influencing people, business and IT experience [14]. The MSIP is planning to support expansion of IoT services and reinforce ICT resource system for commercialization of enterprises. This establishes a sustainable ecosystem of new internet business and create new market solutions. Recently, Korean government has released an initiative to invest 30 trillion won (around US$ 2.7 billion) in IoT testbed advancement for fundamental technological growth and standardization activities.

The MSIP has fostered a blueprint and confirmed an execution strategy for 13 future growth engines like 5th generation (5G) wireless communication and IoT to lead its economic growth till 2020. The main point of the execution plan is to expand the R&D of IoT-related services for future market demands. The 13 growth engines are divided into nine strategic units, in which IoT is listed as one of the four backbone industries. We highlight the details of research plans in the following section.

### 4.2 Research and Development Plans

The MSIP have announced future plan to build a testbed and establish the IoT promotion act. The Ministry has declared "IoT is our future" and determine how to utilize IoT as a new growth engine. The ministry of trade, industry and energy will try and reinforce the competitiveness of manufacturing industry using IoT, thereby bringing in convergence of all industries. The testbed will be built from 2016–2020. Figure 6 shows the purpose of the testbed. The society for supporting establishment of all policies related to IoT will include industrial, academic, research and government experts. The main objectives of this forum is to create,

1. User oriented creative service strategy.
2. R&D to promote the IoT industry.
3. Research works on security and privacy response systems.

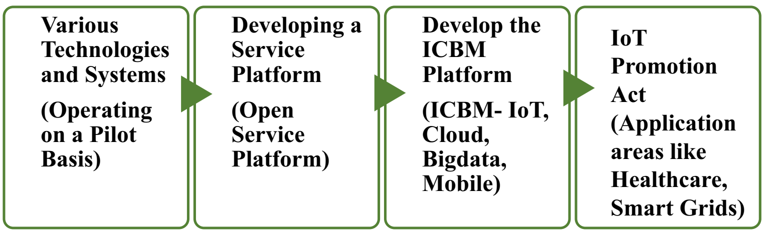



**Fig. 6** Strategies of IoT testbed

4. R&D on ICBM (IoT, Cloud, Bigdata, Mobile).

With these IoT development and emerging research plans, we will now point out the IoT applications already deployed in Korea.

## 5 IoT Applications in Korea

In Korea, the primary application domain of IoT includes, Smart industry, manufacturing applications, Intelligent transportation, Smart grids, Smart homes, Smart healthcare, Smart agriculture, food safety and Smart city. The corresponding uses of these applications are discussed in the following section.

### 5.1 Shipbuilding Industry

Ship building industries are maintaining its global leadership through high value-added services. All the equipments in ship building industry need pervasive information. The government and ETRI have performed field test successfully for Ship Area Network (SAN), which enables and creates the next generation value added services by connecting all equipments and systems of a ship [17, 44]. SAN includes smart security and a smart

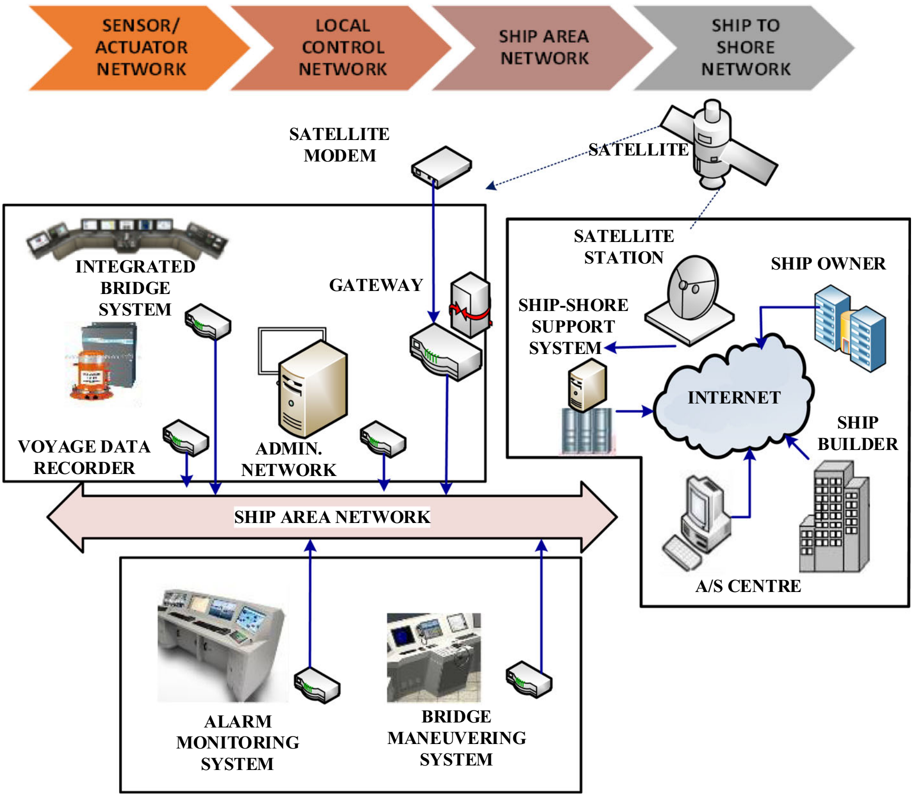



**Fig. 7** Concept of Ship Area Network (SAN) in Korea

ship (global maintenance, repair technology, Intelligent navigation system, auto pilot technique). Figure 7 shows the Ship Area Network operation in Korea.

Another emerging technology in ship building industry is Yard Area Network (YAN)—a concept developed by ETRI for monitoring of real-time movement of blocks and transporters. This assists in improving efficiency of shipbuilding process in shipyard. It also develops a group communication technology for real-time production [17, 44]. Figure 8 shows the Yard Area Network operations in Korea.

### 5.2 Intelligent Transportation System (ITS)

The Korea Expressway Corporation (ex) has implemented the Intelligent Transportation Systems (ITS) in Korea [22]. During the peak hours, a wide number of travelers create huge traffic. The traffic information is collected in real time basis through optical networks. The collection system analyzes and simplifies the information through the operation of Hi-pass. Figure 9 illustrates the concept of ITS. The expressway corporation has developed three different schemes described below:

1. *Expressway Traffic Management System (ETMS)* Roadside CCTVs and Vehicle Detection Systems (VDS) collect the traffic information. This information is analyzed in the traffic information center. This traffic network system provides the analyzed

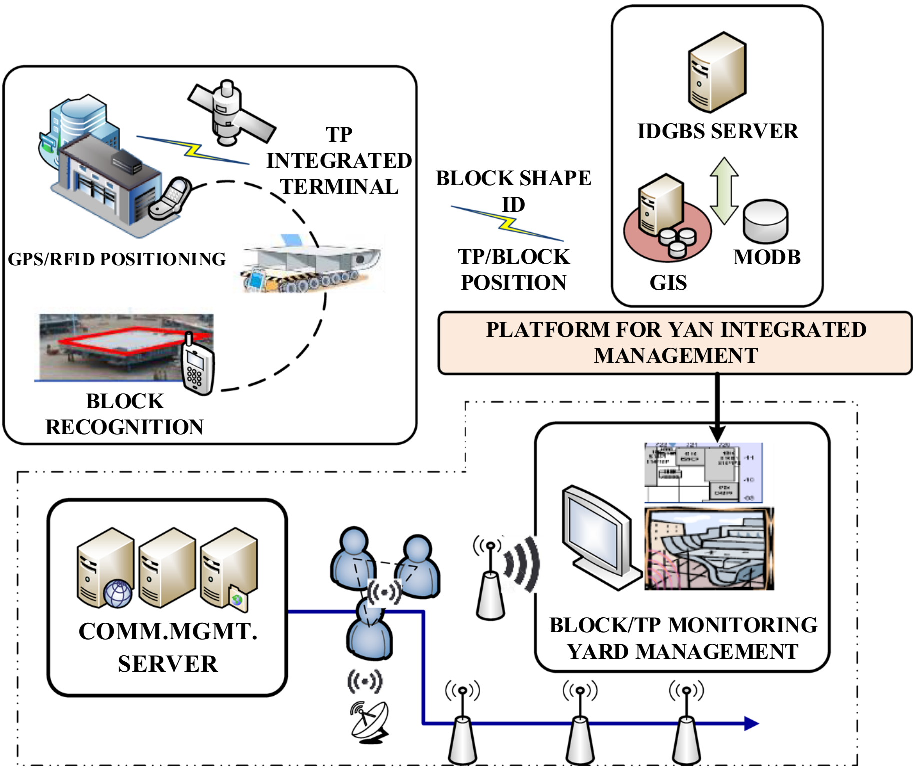



**Fig. 8** Concept of Yard Area Network (YAN) in Korea

information in real time through VMS, Internet, mobile phones, navigation, and the traffic broadcasting station. The major features include the following:

(a) *Closed-Circuit Television (CCTV)*

- Installed on expressways in 2–3 km intervals.
- Identification of delay, congestion, accidents and traffic conditions.
- Transmission of image data through optical cables.

(b) *Automatic Vehicle Classification (AVC)*

- Classifying vehicles into 12 types.
- Estimating traffic volume of each type.

(c) *Vehicle Detection System (VDS)*

- Installed on expressways in 1 km intervals.
- Detecting Information such as traffic volume, speed, occupancy rate, and length of vehicles.
- Monitoring traffic situations and urgent incidents.

(d) *Variable Message Sign (VMS)*

- Installed on interchanges and junctions of expressways.
- Providing customers with information about traffic situation on the road ahead.
- Two types of VMS: Overhead-text type and graphic type.

(e) *Dedicated Short Range Communication (DSRC)*

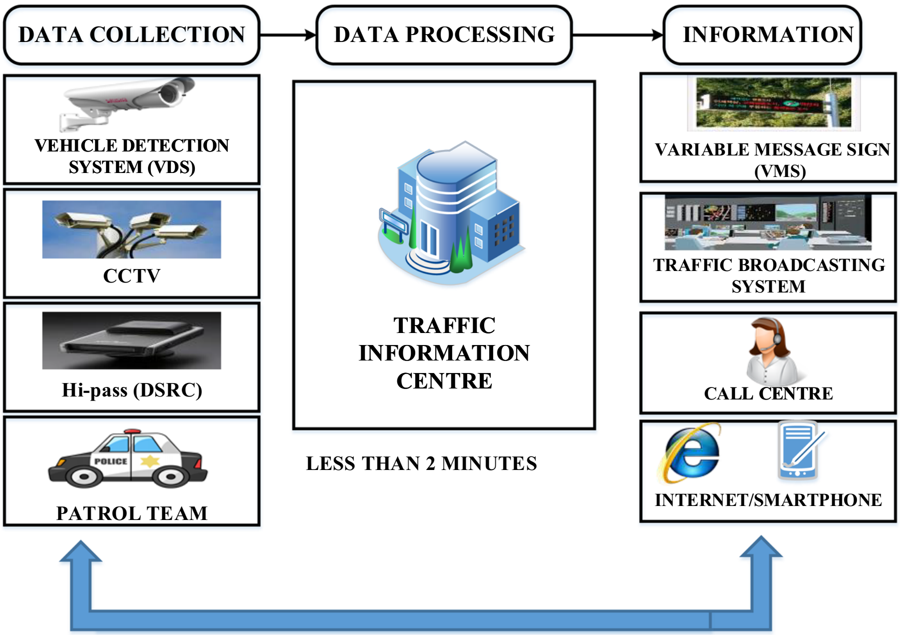



**Fig. 9** Intelligent Transport System (ITS) in Korea

  - Installing DSRC RSE on expressways (per 3.6 km, in total 1845 km).
  - Collecting traffic information from OBUs (On-Board Units).
  - Providing OBU users with traffic situations on the road ahead.

2. *Expressway Toll Collection System (ETCS)* In 2007, ETC (Electronic Toll Collection) was installed in Korean expressways. It reduces the congestion near toll gates dramatically, and allows customers to use expressways more conveniently. The main advantages of the system are:

   (a) *Electronic Toll Collection (ETC): Hi-Pass*

   - ETCS without stopping at toll gates.
   - The world's 1st active-frequency and infrared integrated system.
   - Reducing 40 thousand tons of $CO_2$ emission (2010).
   - Usage rate: More than 50 % of users.

   (b) *Toll Collection System (TCS)*

   - Entrance: Automatically classify vehicles and issue ticket.
   - Exit: Read the ticket and get the information about vehicle.
   - Reducing time for toll collection.

3. *Tunnel Traffic Management System (TTMS)* This system has functions of collecting real-time information of tunnel traffic, detecting accidents and making emergency announcements inside the tunnels. With this application it is possible to respond to incidents quickly and prevent subsequent accidents and congestion inside the tunnels.

## 5.3 Smart Grids (SG)

Korean power grid is one of the advanced smart grid system, which incorporates automated demand response programs. An operating test bed is developed in Jeju Island, Korea [15]. The main driving force behind the roll out of Smart grids lies in its fast response to climate

**Table 4** Smart Grid application in Korea

| Objectives | Phase 1 | Phase 2 |
|---|---|---|
| Smart place | Installing Smart meters in homes and buildings | Real time pricing and smart power generation |
| Smart transportation | Service model for electric vehicles charging | Enhancement of charging facilities |
| Smart renewable | Field test of power stabilization with renewable energy | Identifying new renewable and storing |
| Smart power grid | Two way communication between supplier and consumer | Intelligent distribution system |
| Smart electricity | Real-time pricing and high quality electricity for consumers | Virtual power market |

change, higher energy efficiency, low carbon emissions and green growth. Korean government is now aiming for SG in all metropolitan areas by 2020 and nationwide by 2030. The test bed incorporates smart power grids, smart transportation, green electricity generation and smart place. We summarize the outcomes of phase 1 and visions of phase 2 in Table 4.

### 5.4 Smart Homes

Korea's Pohang University of Science and Technology (POSTECH) is developing three major areas of smart homes: (1) energy management, (2) u-health, and (3) environment control and protection. The system is open, extensible, integrated, intelligent and usage-centric. The ultimate goal is to develop an integrated and multi-faceted home management system, encompassing energy management, home appliance control, environment management, u-health, and living support functionalities under a single unified design [45].

### 5.5 Smart Healthcare

In order to provide safe and high-level medical service to patients, the Next Generation Medical Information System (BESTCare 2.0) has been developed by visualizing patient's data [46]. This helps medical staffs in making faster and intuitive decisions. Major functions include: (1) Core Process—focusing on treatment for patients; (2) Ancillary Service—supporting examination and treatment functions; (3) Intelligent Process Support—ensuring safe treatment for patients; and (4) automated Billing for medical payment and insurance claim. In BESTCare 2.0, an integrated hospital information system, more than 2000 windows are provided in a smart phone application, allowing each medical team to organize and use the individualized user interface. By applying international standards and modularizing functions, different solutions are provided depending on the hospital, nature of the treatment and user requirements. Various data, ranging from the treatment and prescription records of patients to the result of various examinations, are now easily managed. This system is also effective in enhancing medical technologies, as it analyzes disease types and predicts appropriate treatment methods. The major achievements are:

- Excellent compatibility achieved by sharing interface compatibility technology with domestic medical equipment.
- Improved satisfaction of medical teams by enabling fast and effective treatment.
- Improved medical service quality and patients' satisfaction by the reduction in the patient's waiting time and medical service cost.

### 5.6 Smart City

Songdo, a prime example for a smart city, is now being developed in 1500 acres of reclaimed land in Korea [13]. Situated at 40 miles south of Seoul, Songdo will soon be a world-wide model for smart cities. Songdo is a new, connected city, which shares information ubiquitously. This is possible by exploiting new technologies, like IoT, cloud computing and big data. The underlying seamless connection among all the buildings reduce 30 % energy consumption and enables a greener environment. The city is now in the initial phases of development. The city's infrastructure contains sensors, which monitors energy consumption, temperature and city traffic. Songdo also involves smart grid development. It is completely geared towards a sustainable future.

### 5.7 Smart Agriculture and Food Safety

As part of public service promotion program, the state-of-the-art automated facility for raising seedlings has been established [47]. This facility creates cultivating environment, without getting affected by any weather or season. The Smart Farm Factory Crop Container System is built by installing various facilities to artificially foster the basic environment, like temperature, humidity, light source and $CO_2$ required for cultivation. It is done inside a container in such a way that the system and software can be controlled and managed with digital devices like computers and smart phones. Figure 10 depicts the growth modeling process. The crop container is furnished with modern cultivation equipments, like bed soil filling, sowing and transplanting. The required salinity (EC: Electric Conductivity) and hydrogen ion concentration (pH) are measured, and the nutrient concentration is automatically adjusted. The internal environment information is monitored using a remote computer and the basic facilities are adjusted for optimum growth environment. The major achievements are:

– Use of crop container to enhanced labor productivity by minimizing the man-hour, solving the labor shortage in remote areas and optimizing the farmland area.
– Increase in the income of farming villages by improving seedling germination rate by 30 % and transplanting success rate by 90 % in comparison to legacy outdoor farming.

Table 5 discusses the main attributes of the applications in brief. Like any other emerging technology, IoT is also currently facing many open issues. Successful deployment and wide commercialization of IoT depends on efficient solutions of these open issues. In the next section, we would like to highlight the major open issues and the prospect for IoT development in Korea.

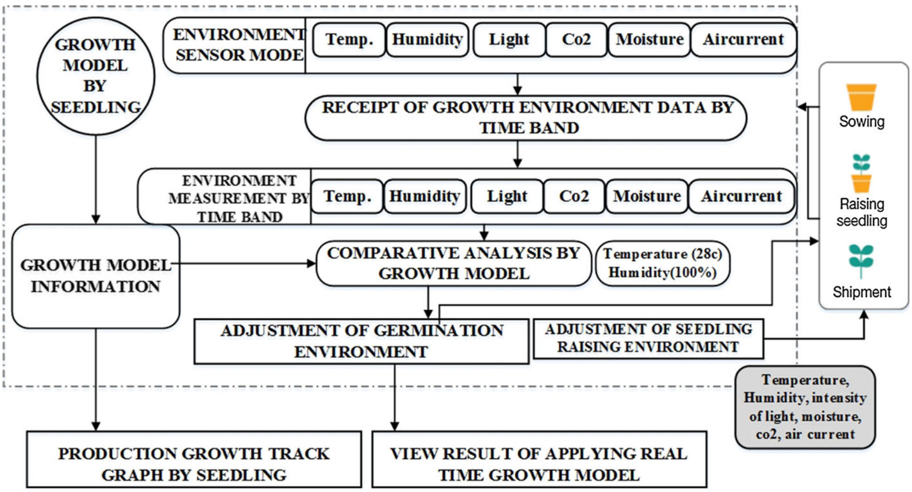



**Fig. 10** Smart farm factory crop container system in Korea

**Table 5** IoT applications in Korea

| Domains | Shipbuilding industry | Intelligent transportation | Smart grids | Smart homes | Smart healthcare | Smart city | Smart agriculture and food safety |
|---|---|---|---|---|---|---|---|
| Network size | Medium/Large | Large | Large | Small | Medium/Large | Medium/Large | Medium/Large |
| Users | Community level, owners | General public | Government, utilities, general public | Very few, family members | General public, government, owners | General public, policy makers, government | Landowners, policy makers |
| IoT devices | RFID, WSN | RFID, WSN | RFID, WSN | WSN, NFC, wearables | Wearables, WSN | RFID, WSN, NFC | WSN |
| Internet connectivity | Wifi, 3G, LTE | Wifi, satellite communication | Wifi, 3G, LTE,satellite communication | Wifi, 3G, LTE | Wifi, 3G, LTE | Wifi, 3G, LTE, satellite communication | Wifi, satellite communication |
| Bandwidth requirement | Medium/Large | Large | Large | Small | Medium | Large | Medium/Large |
| Energy | Rechargeable battery, Energy harvesting | Rechargeable battery | Rechargeable battery, Energy harvesting | Rechargeable battery, Energy harvesting | Rechargeable battery, Energy harvesting | Rechargeable battery, Energy harvesting | Energy harvesting |
| Project name | SAN, YAN [44] | Expressway traffic info.application [22] | Jeju testbed [15] | POSTECH smart homes test bed [45] | BESTcare 2.0 [46] | Songdo [13] | Smart farm factory [47] |
| Applications | Digitized manufacturing, Industrial convergence | Internet of vehicles, Vehicle positioning, Intelligent traffic control | Jeju Testbed, Integrating DER, Demand response programs, Smart meters | Home automation, Wi-fi devices, Mobile computing devices, Home security | Health monitoring devices, Wearable | Seongdo, seoul, Exemplar model, Ubiquitous city, security, Smart homes | Agricultural resources utilization, Quality and safety of food products, Traceability of products |

## 6 IoT: Open Issues and Prospects

As mentioned before, there are many challenges for developing an unified, open, scalable, flexible and service oriented IoT platform. The heterogeneity of various domains with widely different applications and user requirements make the problem even more complex. We illustrate the major issues behind the designing of an IoT system and possible solutions below [48].

### 6.1 Open Issues

Some of the open issues faced by the IoT industry is addressed below.

1. *Standardization Issues* The Standardization activity is critical for commercial roll out IoT. The standards developed needs to be globally acknowledged and applied by multiparty [54]. We have highlighted the major existing standardization efforts in Table 6. In 2012 Korea officially launched Telecommunication Technology Association (TTA), consisting of 267 industries, including Cisco, Huawei, 3M, Intel, IBM, and Oracle [55]. 13 Korean industries, including Samsung Electronics, LG Electronics, SKT, KT, LGU+, are now participating in IoT standardization. The Korean Agency for Technology and Standards (Ministry of Trade, Industry and Energy) announced that Korea has become the chair of the Internet of Things (IoT) Standardization Working Group in International Organization for Standardization (ISO) in 2014 [56].
2. *Architectural Issues* We need an open, scalable, inter-operable architecture in IoT. The architecture should be able to support the context awareness of the events [57, 58] generated by the connected devices. The communication among these connected devices can happen anytime, anywhere in any context. The communication network can be wired, wireless or ad-hoc. Hence, a single architecture cannot be referred for current IoT. This architectural issue is one of the biggest challenge. A Service Oriented Architecture (SOA) is proposed to address this issue.
3. *Networking and Addressing Issues* The technology and the devices used in IoT is extensive for a variety of reasons [59]. IoT uses different distinct network technologies. This includes cellular, WLAN and RFID, with each having its own features. While integrating different technologies, issues like security, scalability and compatibility need to be considered. If not addressed and resolved properly, this may

**Table 6** Standardization activities

| Standardization | Objectives |
|---|---|
| EPCglobal [49] | Integration of RFID into electronic product code (EPC) for product information sharing |
| GRIFS [50] | European initiative on RFID standardization for transition from localized RFID applications to IoT |
| CASAGARAS [7] | International standardization for RFID applications and conformance |
| ETSI M2M [51] | Cost-effective solutions for machine-to-machine (M2M) communications |
| 6LoWPAN [52] | Low-power IEEE 802.15.4 device integration with IPv6 networks |
| ROLL [53] | Routing protocols for heterogeneous, low-power, lossy networks |

hinder IoT development. A conceptual perspective at all stages is the need at the moment. IoT includes an incredibly high number of communicating nodes, each of which will produce content that should be retrievable by any authorized user regardless of its position. This requires effective addressing policies, like IPV6.

4. *Hardware and Software Issues* The objects with embedded intelligence will enable IoT to implement a completely new set of applications, like healthcare [60]. The main research trends of hardware include low cost, small size, low weight and low energy electronic devices. Two main technologies that support IoT are RFID systems and Sensor systems [61]. Diverging hardware requirements significantly increase the challenge. The next difficult part lies in building an unified IoT software platform. This is termed as middleware and it demands a Service Oriented Architecture (SOA). A SOA does not use specific technique or implement a particular service. While most of the projects follow SOA, few projects, like e-sense, have developed middleware solutions based on their own customized requirements [62]. This is also a tough challenge that needs to be addressed.
5. *Privacy and Security Issues* Comparing with existing networks, security and privacy issues are more complicated in IoT [63]. The dynamic activity cycle and heterogeneous interactions demand a security different from the traditional network security. Major issues include data integrity and authentication. The solution methodologies include cryptographic algorithms and light weight encryption technology. This consumes a lot of energy and a few light symmetric key management schemes are proposed [65]. Another impending issue in IoT is privacy. The personal data should be processed with proper privacy and safety. A recent technique on digital forgetting has been recognized [66] to address the major security and privacy issues. The issues are summarized in brief in Table 7.

## 6.2 Prospects for Designing IoT in Korea

IoT industry is gathering momentum around the world and massive developments are underway in Korea, Japan, China, USA and many other countries. The Korean government is sponsoring and promoting IoT with different research institutes, like ETRI and KAIST [17, 67]. Major participants of industrial leaders include Samsung, LG, Korea Telecom.

**Table 7** Open issues and solutions

| Open issues | Solutions |
|---|---|
| Architecture [57, 58] | Open, scalable, interoperable Service Oriented Architecture (SOA) |
| Networking & addressing [59] | Transport protocols to avoid congestion, object addressing, managing data traffic |
| Hardware [60] | Flexible gateways, low energy consumption devices |
| Software [61] | Middleware solutions for heterogeneity, interoperability, security, dependability |
| Security/Privacy [63] | Authentication, confidentiality, integrity, privacy, trusted, robust communication |
| Standardization [64] | Several standardization efforts without comprehensive integration |

We now summarize the major prospects in designing IoT systems in Korea, which has been explained in detail in Sect. 3.

1. In IoT systems, an integrated approach is an utmost requirement. Hence a seamless interaction amongst the various layers is crucial to envisage the vision of IoT. This is the first prospect while designing an IoT system.
2. IoT explores ubiquitous computing over fast reliable networks, with context awareness [68] as a core feature. As the number of connected devices is continuously increasing, context awareness is an important aspect to analyze the big data generated and trigger a suitable action based on that.
3. In IoT people are an integral part. There are few obstacles in socio-technical view for development of IoT in Korea. The main hurdle is linking human with information systems. IoT needs to be made effectively available at the user level.
4. Energy is indispensable to the growth of any country. In near future energy efficiency and sustainability is a major concern. As IoT involves seamless connectivity, the gateways and the nodes consume more power. Hence, new techniques like compact batteries and energy harvesting have a great impact on IoT.

## 7 Conclusion

In this paper we have made a comprehensive review of IoT from Korea's perspective. We first discuss the vision, status and capabilities of IoT. Next, we analyze the global as well as Korean IoT architecture. Subsequently, we have taken an in- depth look into the history and future research plans of Korean public and private IoT industries. We have also pointed out a variety of present and future applications, test-beds and projects, prevalent in Korea. Finally, we point out the major challenges and open issues of IoT and highlight a few possible solutions. We hope our work would assist in IoT development by supporting an increasing number of applications, eventually leading to a new revolutionized internet.

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**Shapna Muralidharan** completed her degree in bachelors of architecture from Thiagarajar College of Engineering, Kamarajar University, India. She is currently pursuing her combined degree Masters and Ph.d in Department of Electrical and Computer Engineering in Sungkyunkwan University, Suwon, South Korea. Her research interests are on Optimizing energy resources in Smart Grids, Green Networking, and Internet of Things (IoT).

**Abhishek Roy** is currently working in, Advanced Technology Group Samsung Electronics South Korea. He received his PhD in 2010 from Sungkyunkwan University, his MS degree in 2002 from the University of Texas at Arlington, USA, and his BE degree in 2000 from Jadavpur University, India. His research interests include mobility and resource management aspects of 4G wireless systems. He serves as an editor and in the technical programme committee of many international conferences. He has co-authored one book (Taylor & Francis) and published in almost 20 international journals.

**Navrati Saxena** is an associate professor in the Electrical Engineering Department, Sungkyunkwan University, South Korea. She worked as an assistant professor in Amity University India and as a visiting researcher in the University of Texas at Arlington. She completed her PhD from the Department of Information and Telecommunication, University of Trento, Italy. Her prime research interests involve 4G/5G wireless and smart environments. She serves as guest editor in the technical programme committee of many international conferences. She has co-authored one book (Taylor & Francis) and published in more than 20 international journals.